

**CO -EXTRACTION OF A HYDROCARBON  
MATERIAL AND EXTRACT OBTAINED BY SOLVENT  
EXTRACTION OF A SECOND HYDROTREATED MATERIAL**

**CROSS-REFERENCE TO RELATED APPLICATIONS**

[0001] This application claims benefit of United States Provisional Patent Applications Serial Nos. 60/450,968 filed February 28, 2003 and 60/464,709 filed April 23, 2003.

**FIELD OF THE INVENTION**

[0002] The present invention relates to a process to increase extraction yields and improve dewaxing performance of a lube boiling range stream. More particularly, the present invention is a process to produce at least one base oil by contacting a light lube stream with a polar solvent in a solvent extraction zone, then mixing the resulting extract with a second, heavier lube stream, extracting the mixture with a polar solvent, and dewaxing the resultant raffinate.

**BACKGROUND OF THE INVENTION**

[0003] The separation of aromatics from hydrocarbon streams by solvent extraction has long been practiced in the refining industry, particularly in the production of lubricating oil. This process involves the use of solvents, such as for example, phenol or N-methyl pyrrolidone ("NMP"), that are selective for extracting aromatic hydrocarbons present in the hydrocarbon streams. During

the extraction process, a hydrocarbon stream and solvent are intimately contacted resulting in the formation of a solvent/aromatics-rich phase commonly called the extract solution and a solvent/aromatics-lean phase commonly called the raffinate solution. Typically, the extract solution and the raffinate solution are separately processed, i.e. stripped, in distillation units to recover the solvent contained in each stream. The stripped hydrocarbon streams are called the extract (aromatics-rich) and the raffinate (aromatics-lean).

[0004] However, because no solvent extraction process can be one hundred percent selective, the aromatics-rich phase typically contains minor, but economically significant, quantities of non-aromatic hydrocarbons that are valuable lube oil molecules. Thus, many processes have been proposed to recover these valuable lube oil molecules. For example, United States Patent Number 4,311,583, teaches that the primary extract solution produced from a solvent extraction process can be further separated by cooling or by the addition of water or a wet solvent. The separation produces a secondary extract solution and a secondary raffinate solution. At least a portion of the secondary raffinate solution is combined with the primary raffinate solution to obtain an increased yield of desired lube oil product. In addition, at least a portion of the

secondary raffinate solution may be mixed with fresh feed entering the extraction zone.

[0005] Likewise, United States Patent Number 5,616,238, teaches that the extract solution produced from a solvent extraction zone can be separated into a pseudo-raffinate solution phase by subjecting the extract solution to water injection in the absence of cooling. The pseudo-raffinate solution is then combined with the feed to the extraction zone without manipulating the flow rate of the solvent so that increased yields of improved products are produced.

[0006] United States Patent Number 5,242,579, also teaches a similar process, although this patent is directed to a method of controlling the solvent extraction process. In this patent, it is taught to solvent extract a feedstock to produce a primary raffinate solution and a primary extract solution phase. The primary extract solution phase is then forced to separate into two phases in a separation zone by lowering its temperature. The separation zone thus produces a secondary extract and a secondary raffinate stream. This secondary raffinate solution stream is passed to the extraction zone to produce an improved yield of primary raffinate having a specified polynuclear aromatic content.

[0007] A process similar to that of United States Patent Number 5,242,579 is taught in United States Patent Number 2,299,426. In this patent, the extract solution produced during the extraction stage is divided and at least a portion is recycled to the lower part of the extraction tower in order to maintain a constant hydraulic loading of the feed distributors.

[0008] However, there still exists a need in the art whereby one can effectively produce a quality base oil through increasing the dewaxing performance and extraction yields of a lube stream.

### **SUMMARY OF THE INVENTION**

[0009] The present invention is a process to improve dewaxing performance and extraction yields from lube oil streams comprising:

- a) contacting a light lube stream in a first solvent extraction zone with a first extraction solvent to produce at least a first aromatics-rich extract solution and a first aromatics-lean raffinate solution;
- b) removing at least a portion of said first extraction solvent from said first aromatics-rich extract solution to produce at least a first aromatics-rich extract;
- c) mixing at least a portion of said first aromatics-rich extract with a heavier lube stream to produce a mixed lube stream;

- d) contacting said mixed lube stream in a second solvent-extraction zone with a second extraction solvent to produce at least a second aromatics-rich extract solution and a second aromatics-lean raffinate solution;
- e) removing at least a portion of said second extraction solvent from said second aromatics-lean raffinate solution to produce at least a second aromatics-lean raffinate; and
- f) dewaxing said second aromatics-lean raffinate to produce at least one base oil.

**[0010]** In one embodiment, the light lube stream is contacted with a hydrocracking catalyst under hydrocracking conditions before said light lube stream is contacted with said first extraction solvent in said first extraction zone.

**[0011]** In another embodiment, the second, heavier lube stream is also contacted with a hydrocracking catalyst under hydrocracking conditions before said heavier lube stream is mixed with said first aromatics rich extract.

[0012] In still another embodiment, the first aromatics-rich extract that is mixed with the heavier lube stream is a mixture of extracts resulting from the separate solvent extraction of at least two different light lube streams.

### **DETAILED DESCRIPTION OF THE INVENTION**

[0013] The present invention provides a process that involves mixing the aromatics-rich extract produced by the solvent extraction of a light lube stream with a heavier lube stream. The mixture of the aromatics-rich extract and the heavier lube stream is referred to herein as a mixed lube stream. The mixed lube stream is contacted with a second extraction solvent in a solvent extraction zone to produce at least a second aromatics-lean raffinate. At least a portion of the second aromatics-lean raffinate is conducted to a dewaxing zone wherein at least one base oil is produced. Through the use of the instant invention, extraction yields are improved because there are good lube-range molecules present in the first aromatics-rich extract. By combining the first aromatics-rich extract with the heavier lube stream and co-extracting them, at least a portion of the good lube-range molecules present in the first aromatics-rich extract can be recovered.

[0014] It should be noted that the phrases "aromatics-lean raffinate solution" and "aromatics-rich extract solution" are not synonymous with the phrases

"aromatics-lean raffinate" and "aromatics-rich extract". The phrases "aromatics-lean raffinate solution" and "aromatics-rich extract solution" are meant to refer to the products of solvent extraction before the solvent has been removed, i.e. distilled or stripped, from the respective phases. Thus, the phrases "aromatics-lean raffinate" and "aromatics-rich extract" refer to the respective products after at least a portion of the solvent contained in the "aromatics-lean raffinate solution" and "aromatics-rich extract solution" has been removed.

[0015] As used herein, aromatics-rich is meant to refer to the concentration of aromatics present in the extract phase produced by solvent extraction in relation to the concentration of aromatics present in the raffinate phase produced by solvent extraction. Also, the use of the word "heavier" in conjunction with "lube stream" is meant to refer to the fact that this lube stream has a higher boiling point in relation to the light lube stream. Likewise, the use of the word light to refer to a lube stream is meant to refer to the fact that this lube stream has a lower boiling point with respect to the heavier lube stream.

[0016] In the practice of the present invention, the light lube stream typically has a mid-boiling point range (50% LV), as determined by ASTM D6417, of about 350°C to about 450°C, preferably from about 375°C to 430°C.

In a most preferred embodiment, the light lube stream used in the practice of the present invention has a mid-boiling point in the range of about 400°C to about 425°C.

[0017] The heavier lube stream referred to herein is distinct from the light lube stream and has a mid-boiling point range greater than 450°C, preferably from 450°C to about 550°C, more preferably from about 460°C to about 525°C, and most preferably from about 465°C to about 490°C. By distinct, it is meant that the heavier lube stream is not generated by "splitting", either mechanically or by temperature separation, the light lube stream into more than one stream. The heavier lube stream is also not a recycle or other stream generated by the processing of the light lube stream.

[0018] It is also preferred that the light lube stream be a hydrocracked light lube stream. Thus, it is preferred to produce the light lube stream by contacting a hydrocarbonaceous feedstream with a hydrocracking catalyst under hydrocracking conditions. The hydrocracking of the hydrocarbonaceous feedstream produces a hydrocracked stream that is subjected to fractionation in the fractionation tower associated with the hydrocracking unit utilized. The fractionation of this hydrocracked stream preferably produces at least two fractions, one of which is a higher-boiling bottoms fraction and one of which is



a lower-boiling lighter fraction. The hydrocracked light lube stream is preferably the lighter fraction.

[0019] It should also be noted that any conventional hydrocracking catalyst can be used in the hydrocracking of the hydrocarbonaceous feedstream. Typical catalysts contain a hydrogenation component and a cracking component. It is preferred that the hydrogenation component is supported on a refractory cracking base. Typical cracking bases include two or more refractory oxides, and typical hydrogenation components are chosen from Group VIB metals, Group VIII metals, their oxides, or mixtures thereof. The conditions under which the hydrocracking is conducted are also conventional. These conditions include reaction temperatures in the range of about 400°F(204°C) to about 800°F(427°C). Total pressures typically range from about 100 to about 1000 psig with hydrogen partial pressures ranging from about 50 to about 450 psig. Typical gas hourly space velocities are between about 200 to about 2000 v/v/hr. Thus, the practitioner of the present invention may utilize any known hydrocracking catalyst known under any known hydrocracking conditions to produce a hydrocracked light lube stream having the above-defined boiling point parameters.

**[0020]** In the practice of the present invention, the heavier lube stream is typically a non-hydrocracked, i.e. conventional, heavier lube stream. However, it is within the scope of the present invention, and preferred, that the heavier lube stream be a hydrocracked heavier lube stream. Thus, the heavier lube stream can be produced by contacting a hydrocarbonaceous feedstream with any known hydrocracking under any known hydrocracking conditions. The hydrocracking of this lube stream also produces a hydrocracked stream that is subjected to fractionation in the fractionation tower associated with the hydrocracking unit utilized. The fractionation of this hydrocracked stream preferably produces at least two fractions, one of which is a bottoms fraction. By bottoms fraction it is meant that fraction having the higher boiling point from the fractionation tower. The heavier lube stream is preferably the bottoms fraction and has the above-defined boiling parameters discussed in relation to the heavier lube stream.

**[0021]** As previously stated, in the practice of the present invention, the above-defined light lube stream is subjected to solvent extraction in a first solvent extraction zone. In the first solvent extraction zone, the light lube stream is contacted with a first extraction solvent. The first extraction solvent can be any solvent known that has an affinity for aromatic hydrocarbons in preference to non-aromatic hydrocarbons. Non-limiting examples of such

solvents include sulfolane, furfural, phenol, and N-methyl pyrrolidone ("NMP"). Furfural, phenol, and NMP are preferred.

**[0022]** The light lube stream can be contacted with the first extraction solvent by any suitable solvent extraction method. Non-limiting examples of such include batch, semi-batch, or continuous. It is preferred that the extraction process be a continuous process, and it is more preferred that the continuous process be operated in a counter-current fashion. In a counter-current configuration, it is preferred that the light lube stream be introduced into the bottom of an elongated contacting zone or tower and caused to flow in an upward direction while the first extraction solvent is introduced at the top of the tower and allowed to flow in a downward direction, counter-current to the upflowing light lube stream. In this configuration, the light lube stream is forced to pass counter-currently to the first extraction solvent resulting in the intimate contact between the first extraction solvent and the light lube stream. The extraction solvent and the light lube stream migrate to opposite ends of the contacting zone.

**[0023]** The conditions under which the first extraction solvent is contacted with the light lube stream include tower top temperatures from about 180°F(82°C) to about 225°F(107°C), preferably from about 160°F(71°C) to

about 205°F(96°C). Tower bottom temperatures are typically about 40°F, preferably 30°F, lower than the tower top temperatures. Pressures typically range from about 0psi(0kPa) to about 20psi(138kPa), preferably from about 5psi(34kPa) to about 15psi(103kPa). In a most preferred embodiment, the temperature and pressure are selected to prevent complete miscibility of the light lube stream in the first extraction solvent.

**[0024]** The contacting of the light lube stream with the first extraction solvent produces at least a first aromatics-rich extract solution and a first aromatics-lean raffinate solution. The first aromatics-rich extract solution is then treated to remove at least a portion of the first extraction solvent contained therein, thus producing the first aromatics rich extract. The removal of at least a portion of the first extraction solvent can be done by any means known in the art effective at separating at least a portion of an extraction solvent from an aromatics rich extract solution. Preferably the first aromatics rich extract is produced by separating at least a portion of the first extraction solvent from the first aromatics-rich extract solution in a stripping or distillation tower. By at least a portion, it is meant that at least about 80 vol.%, preferably about 90 vol.%, more preferably 95 vol.%, based on the first aromatics-rich extract solution, of the first extraction solvent is removed from the first aromatics-rich

extract solution. Most preferably substantially all of the first extraction solvent is removed from the first aromatics-rich extract solution.

**[0025]** However, the removal of at least a portion of the first extraction solvent from the first extract solution is best accomplished by use of vacuum distillation tower that continuously and preferentially separates at least a portion of the first extraction solvent from the hydrocarbon fraction present in the first extract solution. The temperatures at the bottom and top of the vacuum distillation tower can be any temperatures that allow the vacuum distillation to effectively separate at least a portion of the first extraction solvent from the hydrocarbon fraction present in the first extract solution. Preferably, the temperatures at the bottom and top of the distillation tower are about 585°F and 485°F respectively, more preferably about 575°F and 475°F, respectively. Vacuum pressures suitable for use herein can be any pressures that when used allow the vacuum distillation tower to effectively separate at least a portion of the first extraction solvent from the hydrocarbon fraction present in the first extract solution. Preferably, the vacuum distillation tower pressure is 45-60 psig (vacuum), most preferably 50-55 psig (vacuum). It is preferred to recycle the recovered solvent to the start of the extraction process.

[0026] The first aromatics-lean raffinate solution can be passed to further processing. However, it is preferred that the first aromatics-lean raffinate solution be treated in the same manner as the first aromatics-rich extract solution, i.e. be treated to remove at least a portion of the first extraction solvent, to produce at least an aromatics-lean raffinate.

[0027] At least a portion of the first aromatics-rich extract is then mixed with a heavier lube stream. The amount of the first aromatics-rich extract mixed with the heavier lube stream is based on the relative amounts of the first aromatics-rich extract and heavier lube stream available, their physical characteristics, and the degree of improvement desired. Typically, at least a portion is about 5 vol.% preferably about 25 vol.%, more preferably about 35 vol.%, and most preferably about 50 vol.%, based on the aromatics rich extract, of the aromatics-rich extract is mixed with the heavier lube stream. The amount of the first aromatics-rich extract not mixed with the heavier lube stream can be passed to further processing such as, for example, solvent recovery processes or catalytic cracking operations. The amount of first aromatics-rich extract solution or aromatics-rich extract not mixed with the heavier lube stream can also be used to benefit the first solvent extraction zone in any manner. Some beneficial processes are described in the art, such as, for example, those processes described in United States Patent Number 4,311,583,

United States Patent Number 5,616,238, United States Patent Number 5,242,579, and United States Patent Number 2,299,426, all of which have been previously mentioned and all of which are herein incorporated by reference.

[0028] As previously stated, after the first extraction zone, at least a portion of the first aromatics-rich extract is mixed with a heavier lube stream to form a mixed lube stream. Mixing can be accomplished by any suitable technique as long as adequate mixing is achieved. Non-limiting examples of suitable mixing techniques include the use of a storage vessel, an agitated storage vessel, a simple "t-valve", any valve suitable for introducing one stream into another stream, or any other mixing apparatus known in the art that will provide a substantially homogenous mixed lube stream made up of at least a portion of the first aromatics-rich extract and the heavier lube stream. Preferably, they are mixed in a storage vessel.

[0029] The mixed lube stream typically comprises less than about 70 vol.%, based on the total volume of the mixed lube stream, of the first aromatics-rich extract, preferably less than about 50 vol.%, and more preferably less than about 30 vol.%. In a most preferred embodiment, the mixed lube stream comprises about 15 vol.% of the first aromatics-rich extract.

[0030] After mixing, the mixed lube stream is conducted to a second solvent extraction zone that is operated in a manner such that the mixed lube stream is intimately contacted with a second extraction solvent. The second extraction solvent can be selected from those solvents suitable for use in the first extraction zone.

[0031] In the second extraction zone, the mixed lube stream can be contacted with the second extraction solvent by any suitable solvent extraction method or process. Non-limiting examples of such methods or processes include batch, semi-batch, or continuous. It is preferred that the process is a continuous process, and that the continuous process be operated in a counter-current fashion, as previously described.

[0032] The conditions under which the second extraction solvent is contacted with the mixed lube stream include tower top temperatures from about 180°F(82°C) to about 225°F(107°C), preferably from about 160°F(71°C) to about 205°F(96°C). Tower bottom temperatures are typically about 40°F, preferably 30°F, lower than the tower top temperatures. Pressures typically range from about 0psi(0kPa) to about 20psi(138kPa), preferably from about 5psi(34kPa) to about 15psi(103kPa). In a most preferred embodiment, the



temperature and pressure are selected to prevent complete miscibility of the mixed lube stream in the second extraction solvent.

[0033] The contacting of the mixed lube stream with the second extraction solvent also produces at least an aromatics-rich extract solution phase and at least an aromatics-lean raffinate solution phase, referred to herein as the second aromatics-rich extract solution and the second aromatics-lean raffinate solution. The second aromatics-lean raffinate solution is treated, as described above in reference to the first aromatics-rich extract solution, to remove at least a portion of the second extraction solution contained therein, thus producing a second aromatics-lean raffinate. By at least a portion, it is meant that at least about 50 vol.%, preferably about 80 vol.%, more preferably about 95 vol.%, based on the first aromatics-lean raffinate solution, of the second extraction solvent is removed from the second aromatics-lean raffinate solution. Most preferably substantially all of the second extraction solvent is removed from the second aromatics-lean raffinate solution. The second aromatics-rich extract solution can be treated in any manner described above in relation to the first aromatics-rich extract solution. The second aromatics-rich extract solution or the aromatics-rich extract can also be used to benefit the second solvent extraction zone in any manner described in relation to the first solvent

extraction zone. The second aromatics-rich extract can also be sent to solvent recovery processes or catalytic cracking processes.

[0034] After contacting the mixed lube stream with the second extraction solvent, the second aromatics-lean raffinate thus produced is dewaxed in a dewaxing zone wherein at least one base oil is produced. The manner in which the second aromatics-lean raffinate is dewaxed can be any suitable dewaxing method or process. Non-limiting examples of suitable dewaxing methods include catalytic and solvent dewaxing. Preferred is solvent dewaxing. In solvent dewaxing the second aromatics-lean raffinate, it is critical that the second aromatics-lean raffinate and the dewaxing solvent remain as a single phase at the dewaxing temperature. It is especially important that the hydrocarbon molecules and the dewaxing solvent remain as a single phase at the filtration temperature. In other words, the hydrocarbons contained in the aromatics-lean raffinate and the dewaxing solvent must be miscible at the filter temperature because it is extremely difficult to filter a stream that has separated into two phases. Therefore, the miscibility temperature of the hydrocarbons contained in the aromatics-lean raffinate in the dewaxing solvent limits the conditions under which the dewaxing can effectively operate. Lower miscibility temperatures are desirable because this increases the operating flexibility of the solvent dewaxing process. Thus, any way of lowering the

miscibility temperature, i.e. the minimum temperature at which the hydrocarbon and dewaxing solvent are miscible, is very advantageous. The addition of the first aromatics-rich extract to the heavier lube stream lowers the miscibility temperature of the second aromatics-lean raffinate, thus making it easier to dewax.

[0035] In the solvent-dewaxing of the second raffinate phase, an effective amount of any suitable dewaxing solvent may be used, for example, between about 50 and about 700 vol.% solvent to oil ratio, most preferably between about 100 and 500 vol.% solvent to oil ratio may be used. Non-limiting examples of suitable dewaxing solvents include methyl ethyl ketone ("MEK") and methyl isobutyl ketone ("MIBK"). Preferred dewaxing solvents include a mixture of MEK and MIBK, preferred are those mixtures containing about 30 vol.% MEK, based on the total volume of the solvent.

[0036] The base oil produced in the dewaxing stage will typically have a mid-boiling point range (50% LV), as determined by ASTM D6417, of about 400 to about 490°C, preferably about 420 to about 470°C, and will have a Viscosity Index of about 80-120.

[0037] In another embodiment of the present invention, there exists at least two hydrocracked light lube streams that are subjected to solvent extraction to produce at least two aromatics-rich extract phases. These at least two hydrocracked light lube streams are produced in the same manner described above in relation to the light hydrocracked lube stream. Suitable hydrocracking conditions and catalysts are those described above. In this embodiment, the at least two hydrocracked light lube streams are conducted to respective solvent extraction zones wherein the solvent extraction of each hydrocracked light lube stream produces at least one aromatics-rich extract. The solvent extraction processes, solvents, and conditions used in this embodiment are those that are described above. After solvent extraction, at least a portion of the respective aromatics-rich extracts are mixed with a heavier lube stream. Suitable mixing means are those described above. In this embodiment, it is contemplated that the respective portions of the aromatics-rich extracts be mixed prior to being mixed with the heavier lube stream. Suitable mixing means for mixing the respective portions of the aromatics-rich extracts are also those described above in relation to the mixing zone.

[0038] In yet another embodiment of the present invention, the aromatics rich extract phase that is mixed with the heavier lube stream comprises at least a portion of each of the aromatics-rich extracts produced from the solvent

extraction of at least two light lube streams. One of the light lube streams can be a hydrocracked light lube stream, and the other can be a hydrotreated light lube stream, both streams having boiling range characteristics described above in relation to the light lube stream. The hydrocracked light lube stream can be produced by the same hydrocracking process described above. The hydrotreated light lube stream can be produced by contacting a light lube feedstream with a suitable hydrotreating catalyst under hydrotreating conditions. Suitable hydrotreating catalysts include those containing at least one Group VIII metal, such as Ni or Co, and at least one Group VI metal such as Mo or W. Non-limiting examples of preferred hydrotreating catalysts include Ni/Mo on alumina, Ni/W on alumina, Co/Mo on alumina, etc. Conditions under which the hydrotreating is performed include temperatures from about 280°C to about 400°C with hydrogen treat gas rates in the range of about 500 to about 5000 SCF/bbl and liquid hourly space velocities ranging from about 0.1 to 5 v/v/hr (volume of feed/volume of catalyst/per hour). Preferably the hydrotreating is conducted under conditions including temperatures in the range of about 340°C to about 425°C, more preferably 370°C to about 400°C, with hydrogen partial pressures ranging from about 500 to about 2500 psig, more preferably about 1000 to about 1500 psig. It is also preferred to use hydrogen treat gas rates of 1000 to about 2000 SCF/bbl with liquid hourly space velocities ranging from about 0.1 to about 2.0 v/v/hr, more

preferably 0.2 to about 0.5 v/v/hr. After the light lube feedstreams have been subjected to hydrotreating and hydrocracking, the hydrocracked light lube stream and the hydrotreated light lube stream are solvent extracted in respective solvent extraction zones. The solvent extraction is conducted under the same conditions described above with a suitable solvent such as the solvents described above, and the solvent extraction of each stream produces at least one aromatics-rich extract through the process described above, i.e. distillation or fractionation of the aromatics-rich extract solution. At least a portion of each of the aromatics-rich extracts produced through the respective solvent extractions is mixed with a heavier lube stream as described above. Suitable mixing techniques are described above. In this embodiment, it is contemplated that the portions of the respective aromatics-rich extract phases be mixed prior to being mixed with the heavier lube stream. Suitable mixing techniques for mixing the portions of the respective aromatics-rich extracts are also those that are described above in relation to the mixing zone. In this embodiment, it is also contemplated that the at least two light lube streams be hydrotreated light lube streams.

**[0039]** It should be noted that the inventors herein contemplate that the aromatics-rich extract mixed with the heavier lube stream comprise portions of the aromatics-rich extracts produced through solvent extraction of more than

two light lube streams. The more than two light lube streams are preferably hydrocracked light lube streams, hydrotreated light lube streams, or any combination thereof.

[0040] Thus, through the practice of the presently claimed invention a less desirable lube feedstream, the second, heavier lube stream described above, with a variable Viscosity and Viscosity Index, is used to produce a suitable base oil. Extraction yields and dewaxing performance of the second, heavier lube stream are also improved.

[0041] The above description is directed at preferred embodiments of the present invention and it is not intended to limit the invention thereto. One having ordinary skill in the art will recognize that there are modifications and variations that are still within the spirit and scope of the present invention. The inventors herein contemplate any such variations and modifications and contemplate to cover such variations and modifications within the true spirit and scope of the present invention with the attached claims.

[0042] The following examples will be useful in better illustrating the practice of the present invention.

**EXAMPLES**

[0043] In the following examples, a low viscosity aromatics-rich extract was added at various ratios to a high viscosity hydrocracked lube stream and the mixture was solvent extracted using phenol. The raffinates resulting from the solvent extraction of the mixed lube stream were solvent dewaxed under the same conditions to produce dewaxed base oils.

[0044] The following procedure was used to determine the miscibility temperature in all of the Examples below. A 5ml sample of the dewaxed oil (base oil) and 15 ml of ketone or a mixture containing ketone was mixed in a test tube containing a mixer and a thermometer. The mixture was slowly cooled in a bath maintained at  $-32^{\circ}\text{C}$  while under constant stirring until the mixture became cloudy, then it was removed from the bath. The temperature at which the liquid became clear was noted to the nearest  $0.5^{\circ}\text{C}$ . The test was repeated at least two more times and the results were averaged to give the miscibility temperature. The miscibility temperature was determined for three different ketone mixtures, 100%MEK, 80%MEK/20%MIBK, and 60%MEK/40%MIBK. If desired, the miscibility temperature can be plotted against the solvent composition and a line drawn between the points. Above this "miscibility line" the oil/solvent mixture is miscible, and below the line the oil/solvent mixture is immiscible. It should be apparent that lower miscibility



temperatures are very desirable because they allow single-phase dewaxing to be carried out at lower temperatures.

### **EXAMPLE 1**

[0045] A hydrocracked light lube stream having a boiling point range of about 340°C to about 520°C) was solvent extracted using phenol containing 0 to 0.5% water, using a tower top temperature of about 70°C and a bottom tower temperature of about 55°C, (nominally a 15°C tower temperature gradient). The viscosity of the aromatics-rich extract resulting from the solvent extraction was measured according to ASTM D445, and the viscosity was calculated to be 4.861 cSt at 100°C. The aromatics-rich extract was added in 0%, 7.5% and 10% amounts to a heavy hydrocracked lube stream boiling between about 400°C and 620°C and having a viscosity of 7.716 cSt at 100°C, according to ASTM D445, to form mixed lube streams. Each mixed lube stream was phenol extracted under conditions including 1.5% water in the phenol solvent, 1 to 2 v/v solvent/oil, 90°C tower top temperature/75°C tower bottom temperature to produce second aromatics-rich raffinate solutions. The phenol was removed from the raffinate solutions using vacuum distillation to produce aromatics-rich extracts for each of the respective mixed lube streams.

[0046] The aromatics-rich raffinates were each solvent dewaxed using dry 30% MEK/ 70% MIBK, 3:1 v/v solvent/oil at  $-18^{\circ}\text{C}$  filter temperature and the solvent was removed using vacuum distillation. The miscibility temperatures of each of the dewaxed oils in dry MEK/MIBK mixtures were measured by the method outlined above. The pour point of the base oils recovered after dewaxing was measured according to ASTM D5949. Also, the raffinate yield on total feed was calculated by averaging the Refractive Index (RI) yield and the Density yield, defined by the following formulae:

$$\text{RI Yield} = \frac{(\text{Extract RI at } 75^{\circ}\text{C} - \text{Feed RI at } 75^{\circ}\text{C}) * 100}{(\text{Extract RI at } 75^{\circ}\text{C} - \text{Raffinate RI at } 75^{\circ}\text{C})}$$

$$\text{Density Yield} = \frac{(\text{Extract Density at } 75^{\circ}\text{C} - \text{Feed Density at } 75^{\circ}\text{C}) * 100}{(\text{Extract Density at } 75^{\circ}\text{C} - \text{Raffinate Density at } 75^{\circ}\text{C})}$$

[0047] The results are reported in Table 1 below.

**TABLE 1**

% extract added	Raffinate yield on total feed, %	Raffinate yield on fresh feed, %	Dewaxed oil pour point, $^{\circ}\text{C}$	Miscibility temperature, $^{\circ}\text{C}$			
				In 100% MEK	In 80% MEK	In 60% MEK	In 40% MEK
0	96.2	96.2	-13	22.0	12.5	3.0	-9.5
7.5	94.8	102.5	-12	21.5	11.5	2.0	-10.5
10.0	94.3	104.8	-12	21.0	11.0	1.0	-11.0

[0048] As can be seen from the results contained in Table 1, the raffinate yield based on the heavy hydrocracked lube stream increased as the amount of aromatics-rich extract added was increased. Thus, valuable lube molecules were recovered from the aromatics-rich extract. For oils dewaxed at  $-18^{\circ}\text{C}$  filter temperature, miscibility temperatures became progressively lower as the percentage of extract added to the heavy hydrocracked lube stream was increased. The decrease in miscibility temperatures indicates that these base oils would be easier to dewax.

## **EXAMPLE 2**

[0049] The raffinates produced in Example 1 were dewaxed at  $-12^{\circ}\text{C}$  filter temperature using dry 30% MEK/ 70% MIBK under conditions including 3:1 v/v solvent/oil at  $-18^{\circ}\text{C}$  filter temperature and the solvent was removed using vacuum distillation. Miscibility temperatures were measured according to the same procedure outlined in Example 1 above. The pour point of the base oils recovered after dewaxing was measured according to ASTM D5949. Also, the raffinate yield was calculated using the formulae defined in Example 1. The results are reported in Table 2 below.

**TABLE 2**

% extract added	Raffinate yield, %	Dewaxed oil pour point, °C	Miscibility temperature, °C			
			In 100% MEK	In 80% MEK	In 60% MEK	In 40% MEK
0	96.2	-10	18.4	8.6	-0.4	-10.8
7.5	94.8	-10	-17.4	8.1	-1.8	-11.6
10.0	94.3	-9	17.1	7.5	-1.9	-11.8

[0050] It is seen that for oils dewaxed at  $-12^{\circ}\text{C}$  filter temperature, miscibility temperatures became progressively lower as the percentage of extract added was increased. This indicates that these raffinates would be easier to dewax.